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2 Electronic Supplementary Information

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6 **Novel fungus-titanate bio-nano composites as high performance**  
7 **absorbents for the efficient removal of radioactive ions from**  
8 **wastewater**

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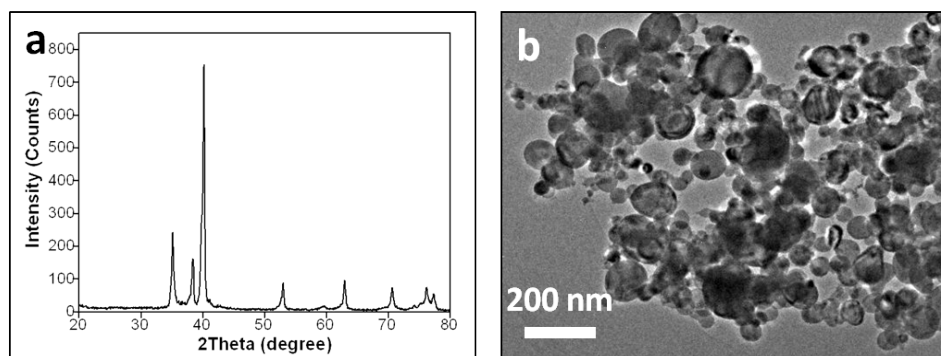
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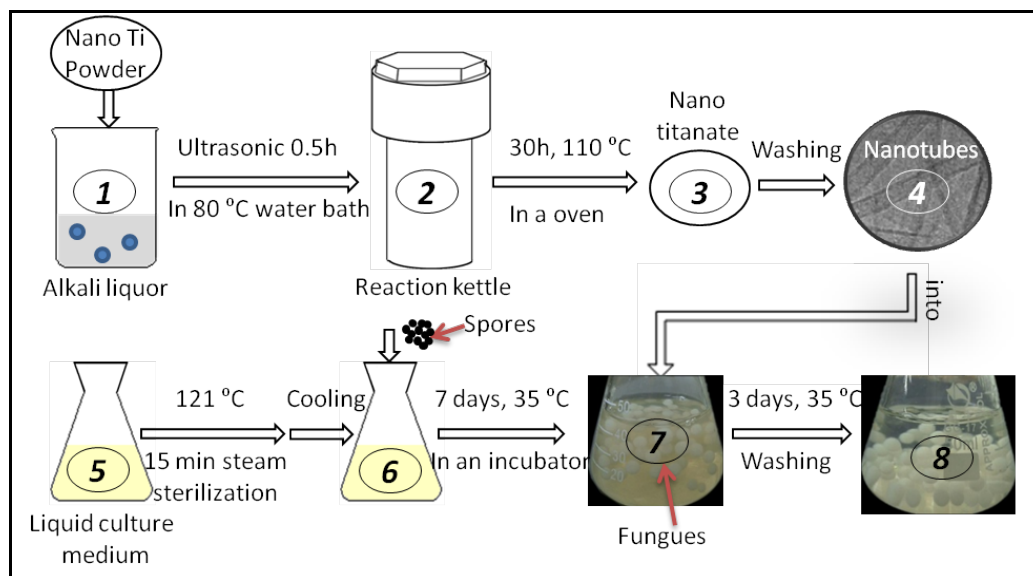
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## 1 Experimental section

2 The chemical reagents used in this batch experiments, such as hydrochloric acid, sodium  
3 hydroxide and ethanol were of analytic grade without any further purification. High purity Ti  
4 nanopowders with an average particle size of 50 nm (XRD and TEM characterizations can be found  
5 in Fig. S1(a) and (b)) and specific area of  $14 \text{ m}^2 \text{ g}^{-1}$  were purchased from the Gao Sida nanomaterials  
6 equipment company in Siping city, China. Procedure chart of the preparation of fungus-titanate  
7 nanotubes bio-nano composites is shown in Fig. S2.



8  
9 **Fig. S1.** (a) XRD pattern of Ti nanopowders, all the diffraction peaks can be indexed to titanium (JCPDS-65-9622).  
10 (b) Typical TEM image of Ti nanopowders, revealing that the average particle size is of 50 nm.  
11



12  
13 **Fig. S2.** Preparation procedure chart for producing the bio-nano composites. (1-4) are the relative preparation flow  
14 for the preparation of titanate nanotubes from the raw nano metal Ti powders. (5-6) are the preparation steps for the  
15 preparation of fungus. (7-8) are the relative preparation steps of bio-nano composite by adding titanate nanotubes  
16 into the fungus solution.

### 17 1.1 The preparation of titanate nanotubes (Steps: 1-4, Fig. S2)

1 The method for prepared titanate nanotubes was the same as that reported in our previous paper  
2 (*J. Nanosci. Nanotechnol.* 12, 6374 (2012)). In a typical process: Firstly, 0.3 g of metal Ti  
3 nanopowders were mixed with 30 mL of 10 mol/L NaOH solution in a beaker, then the beaker was  
4 placed into an ultrasonic bath with ultrasonication for 0.5 h. Subsequently, the suspension was  
5 transferred into a reactor with an inner wall of poly-tetrafluoroethylene followed by heated in the  
6 oven maintained at 110 °C for 30 h. After the reactor cooled to room temperature naturally in the  
7 oven, the resultants (white powders) were treated with diluted HCl solution deionized water and then  
8 centrifuged to separate the powders from the solution in turn. This procedure was repeated until the  
9 pH of the solution is about 7. Finally, the white powders were obtained after dried at 60 °C for 2 h.

### 10 **1.2 The cultivation of fungus (Steps: 5-6, Fig. S2)**

11 A conventional liquid culture medium for the cultivation of fungus was mixed with beef extract  
12 peptone (1.6%), glucose (2%), glycerol (0.5%) and water (95.9%), then treated with the traditional  
13 high-temperature sterilization method. Spores of black aspergillus were cultivated to the liquid  
14 culture medium in an aseptic bench. After they were allowed to grow at 35 °C for seven days in a  
15 constant temperature shaking incubator, small parts of the mycelia were removed from the culture  
16 medium by using a tweezers for the preparation of bio-nano composites.

### 17 **1.3 The preparation of bio-nano composites (Steps: 7-8, Fig. S2)**

18 Firstly, ~0.5g titanate nanotubes with a BET specific surface area of 260 m<sup>2</sup> g<sup>-1</sup> were dispersed  
19 into the solution containing 0.6 g funguses (dry weight). Subsequently, the mixed solution was  
20 placed into the incubator oscillation for 3 days to grow the composites. After growth of composites,  
21 the bio-nano composites were washed several times with ethanol to remove the dissociative and  
22 unadhered titanate nanotubes from the composites. Finally, the bio-nano composites were obtained  
23 after dried at 60 °C for 6 h.

### 24 **1.4 The preparation of mixed sample for FTIR characterization**

25 The sample was produced via a simple mechanical mixing of titanate nanotubes and black  
26 aspergillus in a certain proportion (0.36:0.64), and then ground in a mortar about 2 hours with the  
27 help of adding small quantities of ethanol solution until there are no obvious white titanate particles.  
28 After aged three days at room temperature, the mixed sample can be used for FTIR characterization.

## 1 1.5 The preparation of Ba<sup>2+</sup> ions solution

2 According to experiment requirements, a batch of solution with different Ba<sup>2+</sup> ion concentrations  
3 in the range of 8 mg L<sup>-1</sup> to 200 mg L<sup>-1</sup> were prepared for using in the absorption tests. In a typical  
4 process, a certain amount of Ba(NO<sub>3</sub>)<sub>2</sub> powders were firstly weighed and then dissolved in a 1 L  
5 deionized water to prepare solutions with a certain concentration. The removal of Ba<sup>2+</sup> ions were  
6 determined by equilibrating 30 mg bio-nano composites in 30 mL Ba<sup>2+</sup> ions solutions at room  
7 temperature.

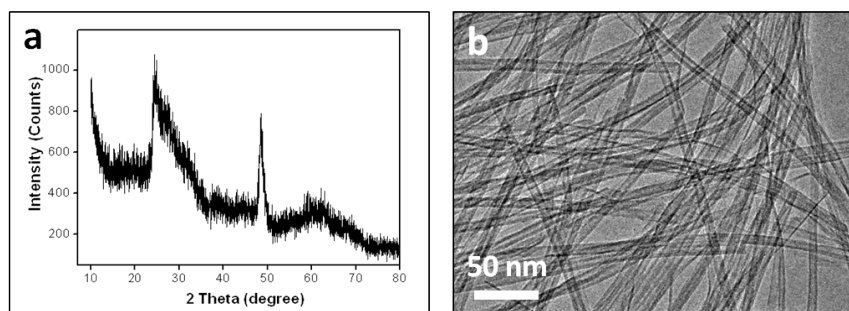
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## 9 2 Characterizations

10 The powder XRD patterns were recorded on a Rigaku D/Max 2550 X-ray diffractometer with  
11 Cu K $\alpha$  radiation ( $\lambda=1.5418$  Å). The transmission electron microscopy (TEM), SAED and HRTEM  
12 images were obtained on a JEOL JSM-2800 TEM microscope operating at 200 KV. Fourier  
13 transform infrared spectroscopys (FTIR, AVATAR 370 DTGS) can be recorded by using a KBr pellet  
14 technique. Finally, the concentration of Ba<sup>2+</sup> ions in the aqueous solution after adsorption test was  
15 analyzed by inductively coupled plasma optical emission spectrometer (ICP-OES, OPTIMA  
16 3300DV).

### 17 2.1 The characterizations of titanate nanotubes

18 The used titanate nanotubes to prepare bio-nano composites have the same crystalline phase and  
19 morphological characterizations as those reported in our early work (XRD and TEM  
20 characterizations can be found in Fig. S3(a) and (b)). And the specific surface area of titanate  
21 nanotubes is as high as 260 m<sup>2</sup> g<sup>-1</sup>.



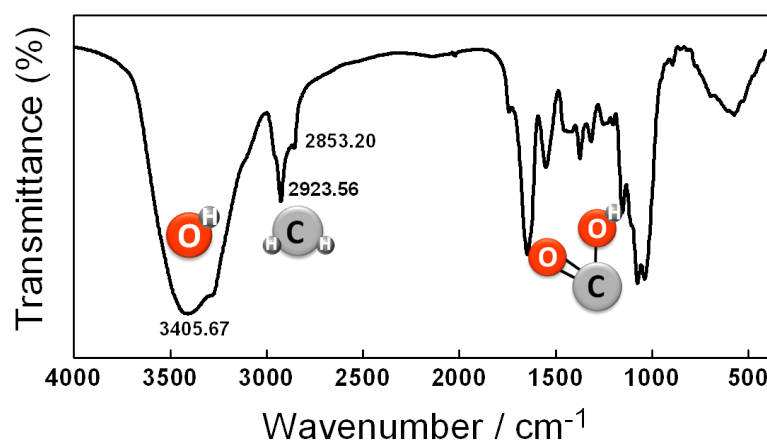
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23 **Fig. S3.** (a) The XRD pattern of nanotubes can be indexed to H<sub>2</sub>Ti<sub>2</sub>O<sub>4</sub>(OH)<sub>2</sub>. (b) The typical  
24 TEM characterizations of length ranged in 200~500 nm and a diameter ranged in 5~20 nm.

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## 1 2.2 The FTIR of pure black aspergillus

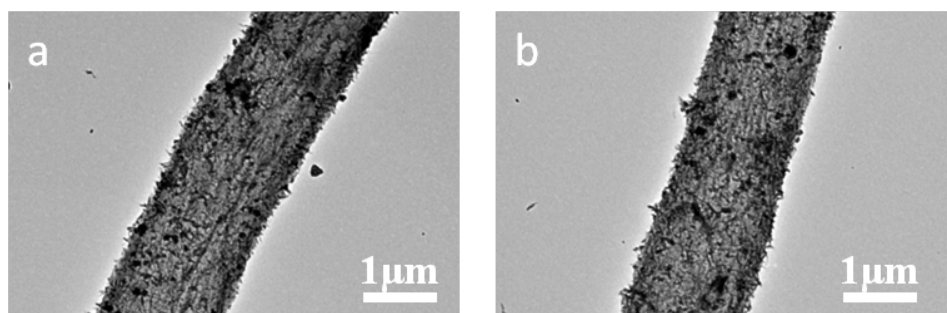
2 FTIR spectroscopy of pure black aspergillus obtained via the experiments described in  
3 the section 1.2 was shown in Fig. S4. From the picture, the absorption band centered at  $3405\text{ cm}^{-1}$  is  
4 the characteristic band of stretching vibrations of hydroxyl of water. Bands at  $2923$  and  $2853\text{ cm}^{-1}$   
5 can be assigned to  $-\text{CH}_2$  asymmetrical stretch and  $-\text{CH}_2$  symmetrical stretch, respectively. The region  
6 between  $1750$  and  $900\text{ cm}^{-1}$  can be assigned to be the bands of protein, fatty acid and polysaccharide  
7 region of microorganisms.



8  
9 **Fig. S4.** The FTIR spectroscopy of pure black aspergillus without adhered titanate nanotubes

## 10 2.3 TEM images of composites before and after an hour ultrasonic process

11 As shown in Fig. S5, it is clear that the two samples are almost the same and there is no clear  
12 evidence of a decline in adhered titanate nanotubes numbers after an hour ultrasonic process. The  
13 composites can still remain original structure and titanate nanotubes can still cover the surface of the  
14 whole fungus. The fact can be directly used for verifying that our composites are stable enough to  
15 withstand one hour ultrasonic process and some chemical bonds indeed exist between the nanotubes  
16 and the fungus.



17  
18 **Fig. S5.** TEM images of the black aspergillus-titanate nanotubes composites: without ultrasonic treatment (**a**) and  
19 after an hour ultrasonic treatment (**b**), respectively.